

**SOME ASPECTS OF  
CHEMICAL AND BIOLOGICAL DYNAMICS  
IN RELATION TO  
TIME EVOLVING STRUCTURES**

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# Fantasy?

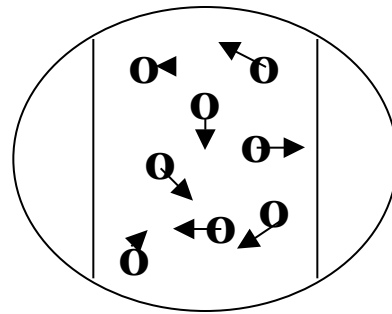
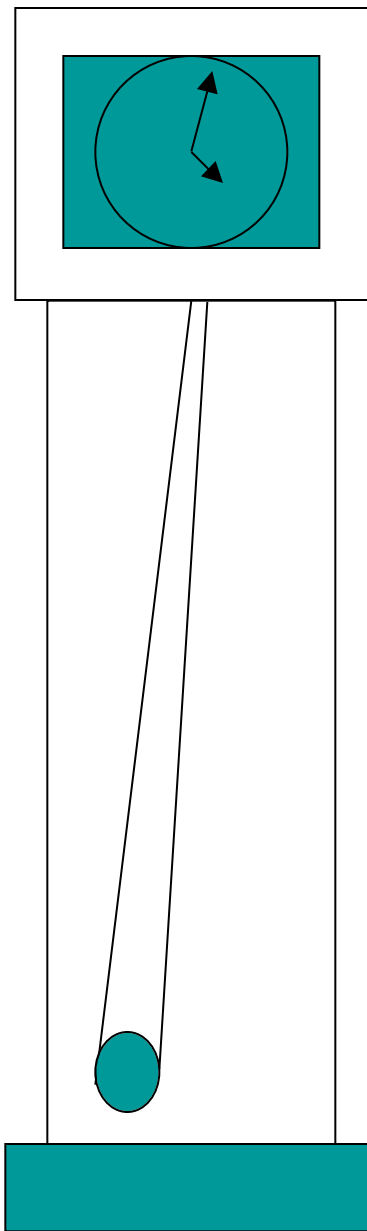
- The ideal approach in structural biology would obtain atomic scale structures during the course of biochemical processes in functional environments such as solutions and membranes.
- **Is this feasible?** In crystals, yes (Moffat, Anfinrud) otherwise, not yet.
- **What is the answer?** Develop many approaches to determining evolution of structural features, each with its special strength.
- **What time scales?** Ultrafast? Ultraslow? All are needed

**“SOME ASPECTS OF CHEMICAL AND BIOLOGICAL DYNAMICS IN RELATION TO TIME EVOLVING STRUCTURES....”**

**MOST CHEMISTRY AND BIOLOGY TAKES PLACE IN LIQUID SOLUTIONS – OFTEN IN WATER.**

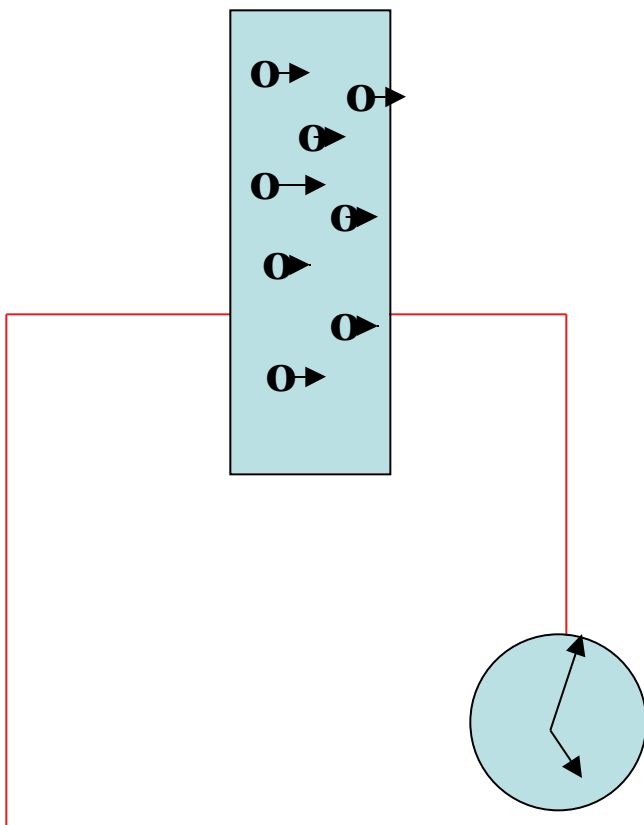
**THEREFORE IT IS IMPORTANT TO TRACK NUCLEAR MOTIONS OF COMPLEX MOLECULE IN SOLUTIONS.**

Are all atomic motions  
important in biology?



Which motions  
influence the operation  
of the clock?

BUT IN OTHER CASES:



Quartz watch

# **NEED TO COMBINE DIFFRACTION AND SPECTROSCOPY**

## **SYNCHRONOUS**

X-RAYS

;

IR/OPTICAL  
PULSE SEQUENCES

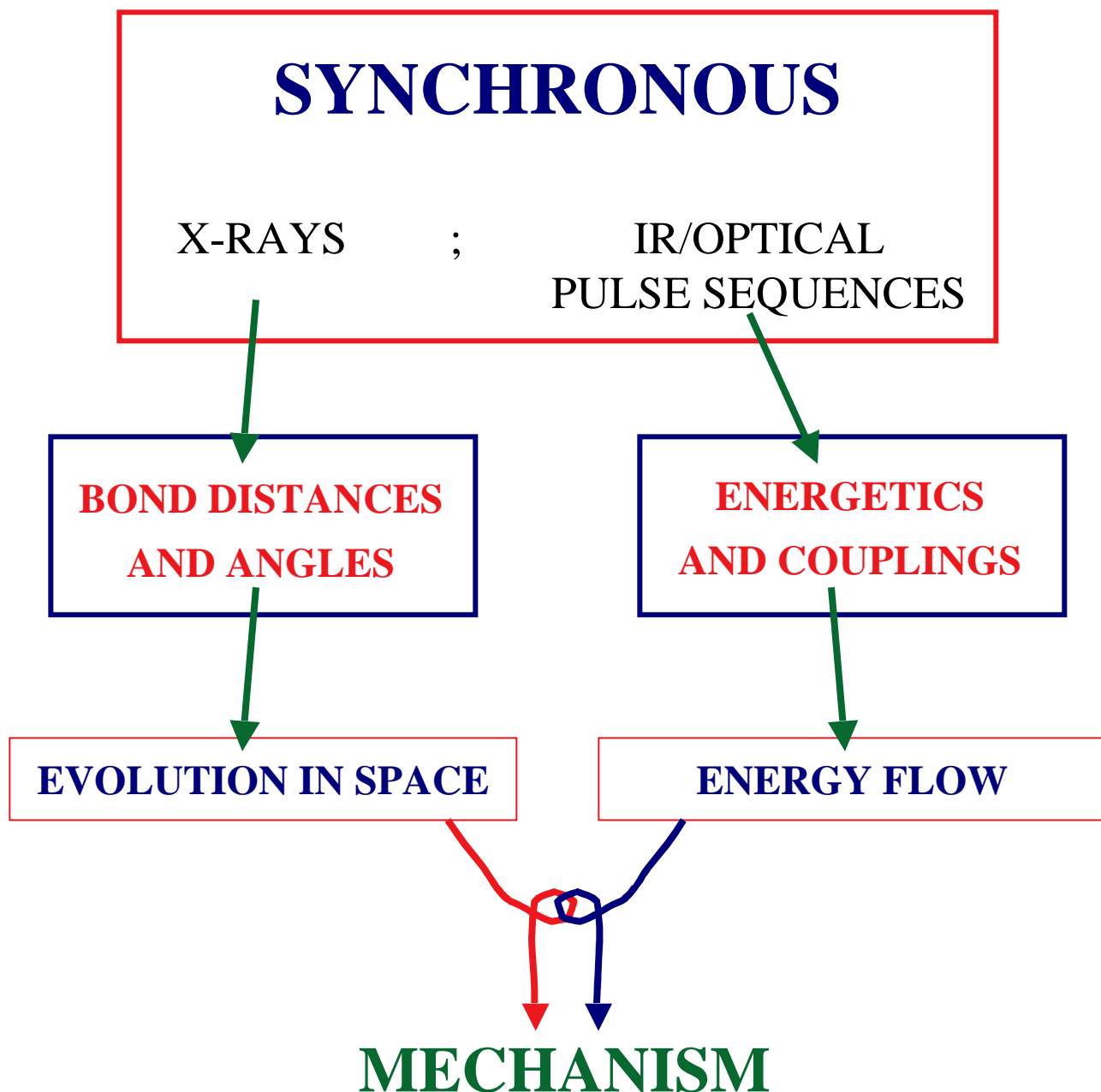
**BOND DISTANCES  
AND ANGLES**

**ENERGETICS  
AND COUPLINGS**

**EVOLUTION IN SPACE**

**ENERGY FLOW**

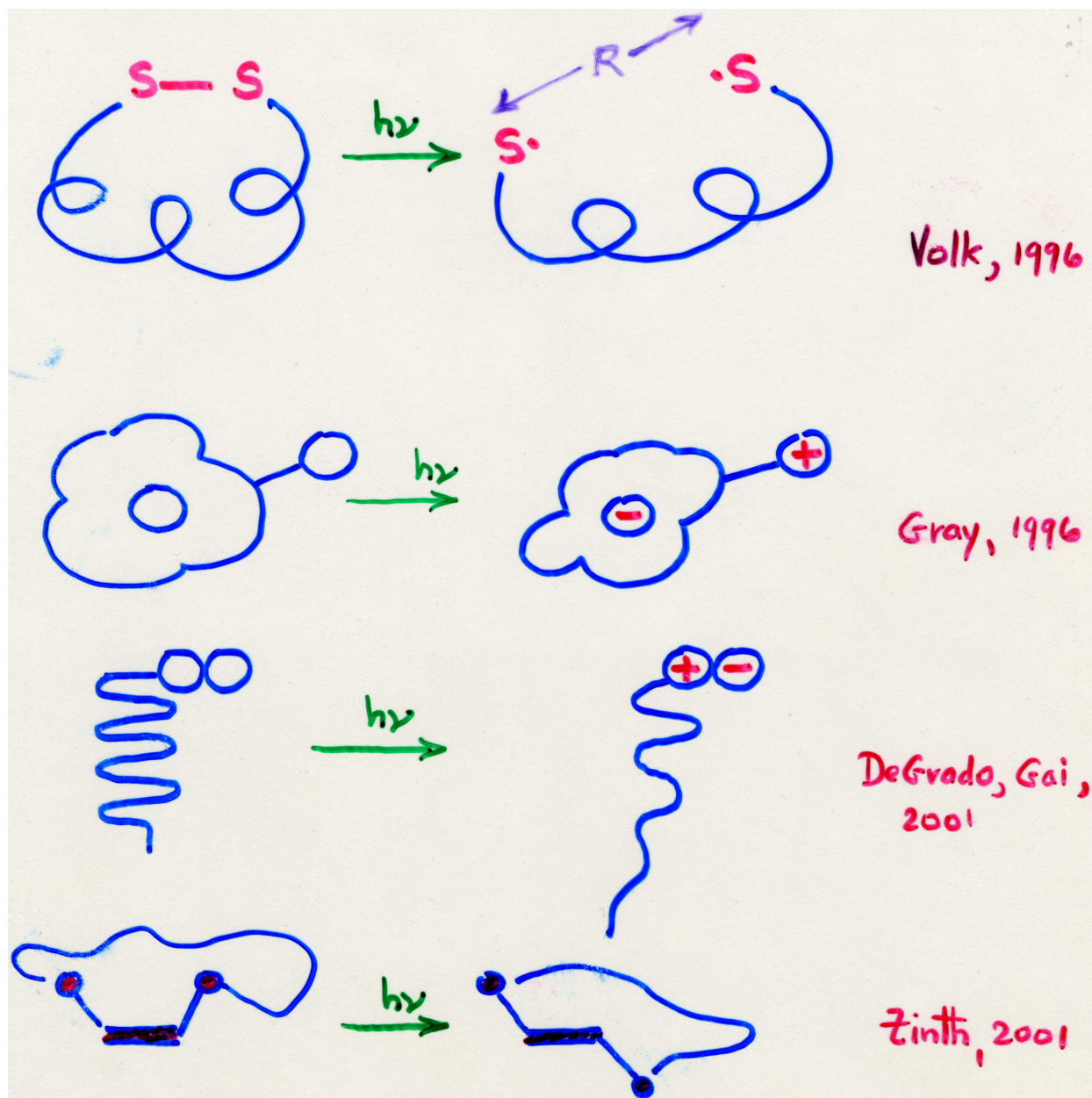
**MECHANISM**



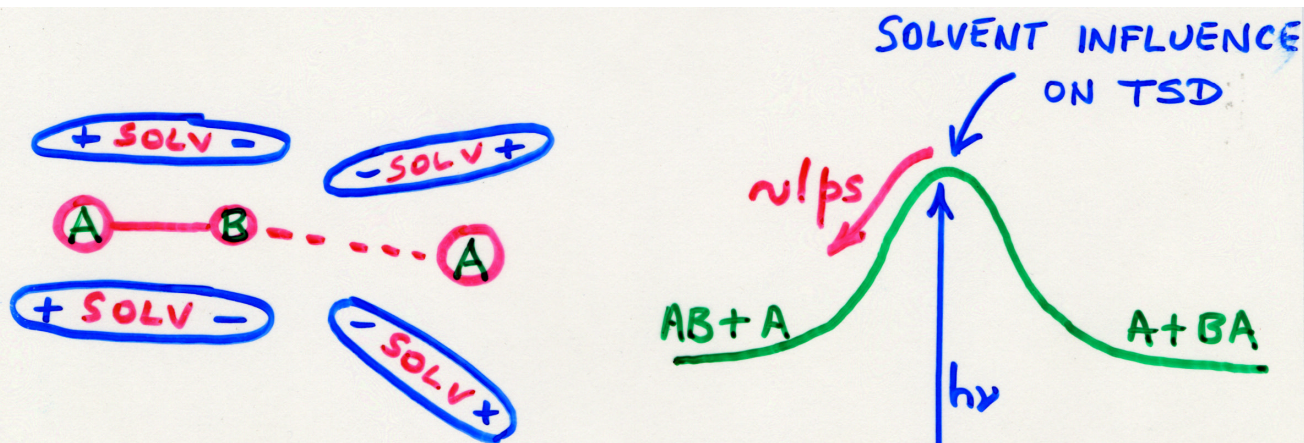
# Methods of triggering biochemical processes

- **Photolysis**: ultrafast, applicable to photobiology or phototriggerable systems, natural or synthetic.
- **Rapid mixing**: microsecond processes; very general. Most biochemical kinetics come from this source.
- **Temperature jumps**: timescales longer than ca. 50 ps
- **Optically induced pH Jumps**: time scales longer than 50 ps
- **High pressure jumps**: ms time scale diffraction

# EXAMPLES OF ULTRAFAST TRIGGERS OF CONFORMATIONAL DYNAMICS



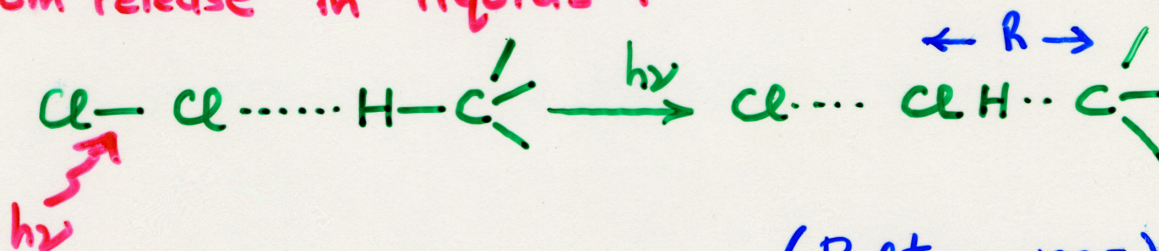
# TRIGGERING BIMOLECULAR REACTIONS IN LIQUIDS



initial structure from  
X-ray scattering  
(Sandstrom, 1972)

(Soep, 1980)

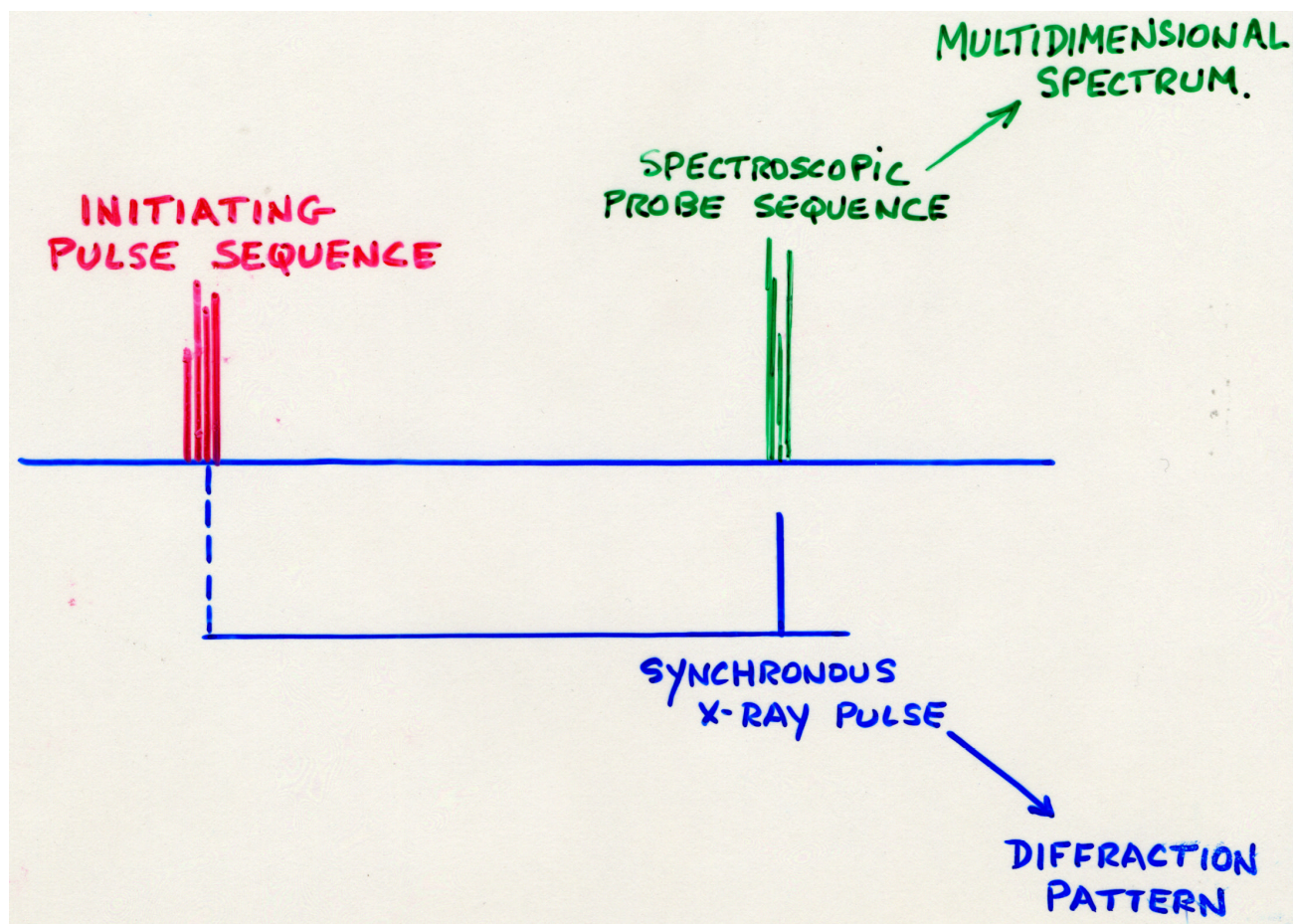
Atom release in liquids :



(Raftery, 1995)

# MEASUREMENT OF SOLUTION PHASE STRUCTURAL CHANGES

- RADIAL DISTRIBUTION  
RESPONSES IN PERTURBED  
LIQUIDS
- CONFORMATIONAL  
DYNAMICS WITH ULTRAFAST  
TRIGGERS
- BIMOLECULAR REACTIONS IN  
SOLUTIONS
- COMBINE X-RAY PULSE  
PROBING WITH OPTIMIZED  
(MULTIDIMENSIONAL)  
SPECTROSCOPIES.



MULTIPLE-PULSE COHERENT METHODS, SUCH AS 2D AND 3D INFRARED SPECTROSCOPY, PROVIDE DYNAMICS, ENERGETICS AND STRUCTURAL EVOLUTION – COMPLEMENTS TO X-RAY PULSE PROBES

# Structural constraints from 2D IR

- Distance: Models for mixed mode anharmonicities yield:

$$1/R^3 \quad \text{3 to 9 \AA scale.}$$

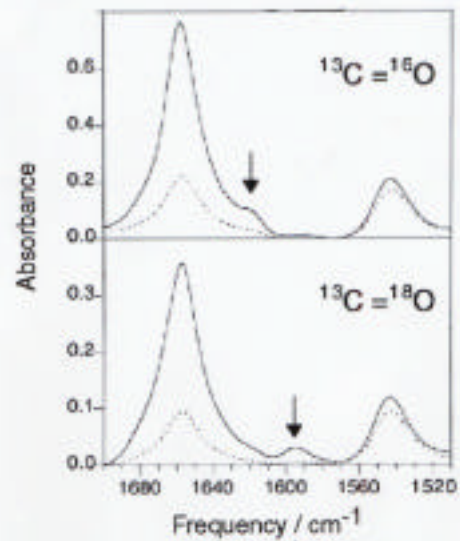
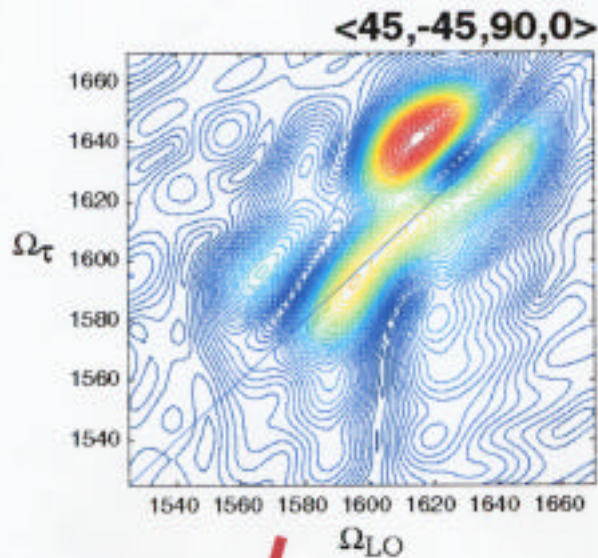
- Angles: Model independent, each cross peak may yield,

$$P_1 \text{ and } P_2$$

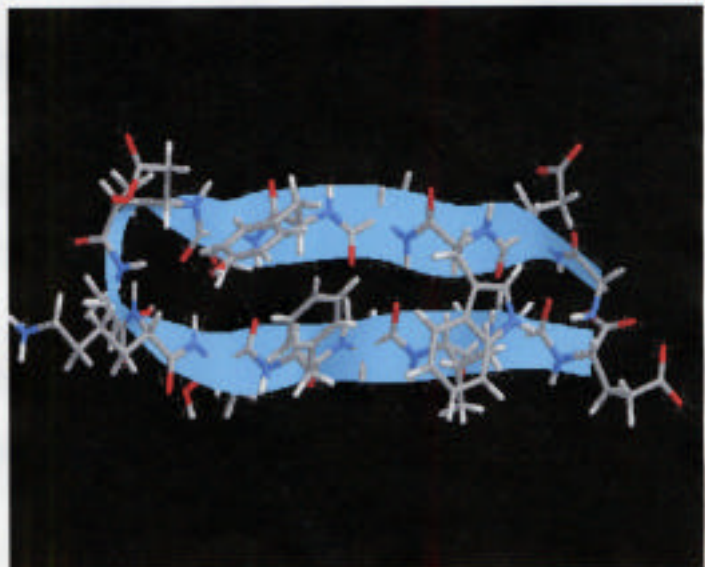
- Energy transport:

$$\sim 1/R^6$$

Isotopic replacement selects required structural components



alpha helix



$\beta$ -hairpin